

## CLAIMS

What is claimed is:

- 1           1.       An apparatus comprising:
  - 2           a first balancer to generate a first balancing signal from a first signal of a first index
  - 3           corresponding to a first frequency; and
  - 4           a first combiner coupled to the first balancer to combine the first balancing signal
  - 5           and a second signal of a second index corresponding to a second frequency, the second
  - 6           frequency being symmetrical to the first frequency with respect to a center frequency in a
  - 7           multi-carrier signal, the first combiner generating a first balanced signal corresponding to
  - 8           the second frequency.
- 1           2.       The apparatus of claim 1 wherein the first balancer comprises:
  - 2           a first converter to convert the first signal into a first complex conjugate; and
  - 3           a first multiplier coupled to the first converter to multiply the first complex
  - 4           conjugate with a first balancing parameter, the first balancing parameter corresponding to
  - 5           the first frequency, the first multiplier generating the first balancing signal.
- 1           3.       The apparatus of claim 1 wherein the first combiner includes a first
  - 2           subtractor to subtract the first balancing signal from the second signal to provide the first
  - 3           balanced signal.
- 1           4.       The apparatus of claim 1 wherein the first balanced signal is a first desired
  - 2           signal scaled by a first complex factor.
- 1           5.       The apparatus of claim 1 wherein the first signal is provided by a first sub-
  - 2           carrier demodulator operating at the first frequency.
- 1           6.       The apparatus of claim 4 wherein the first desired signal is a first
  - 2           demodulated signal.
- 1           7.       The apparatus of claim 1 further comprising:

2 a second balancer to generate a second balancing signal from the second signal; and  
 3 a second combiner coupled to the second balancer to combine the second balancing  
 4 signal with the first signal at a second frequency, the second combiner generating a second  
 5 balanced signal at the first frequency.

1 8. The apparatus of claim 7 wherein the second balancer comprises:  
 2 a second converter to convert the second signal into a second complex conjugate;  
 3 and  
 4 a second multiplier coupled to the second converter to multiply the second complex  
 5 conjugate with a second balancing parameter, the second balancing parameter  
 6 corresponding to the second frequency, the second multiplier generating the second  
 7 balancing signal.

1 9. The apparatus of claim 7 wherein the second combiner includes a second  
 2 subtractor to subtract the second balancing signal from the first signal to provide the  
 3 second balanced signal.

1 10. The apparatus of claim 7 wherein the second balanced signal is a second  
 2 desired signal scaled by a second complex factor.

1 11. The apparatus of claim 7 wherein the second signal is provided by a second  
 2 sub-carrier demodulator operating at the second frequency.

1 12. The apparatus of claim 10 wherein the second desired signal is a second  
 2 demodulated signal.

1 13. The apparatus of claim 2 wherein the first balancing parameter is a ratio  
 2 between output of the second sub-carrier demodulator and a conjugate output of the first  
 3 sub-carrier demodulator when the multi-carrier signal contains a first sub-carrier signal  
 4 modulated by a non-null complex number and a second sub-carrier signal modulated by a  
 5 null complex number during a training process.

1           14.     The apparatus of claim 8 wherein the second balancing parameter is a ratio  
2     between output of the first sub-carrier demodulator and a conjugate output of the second  
3     sub-carrier demodulator when the multi-carrier signal contains a first sub-carrier signal  
4     modulated by a null complex number and a second sub-carrier signal modulated by a non-  
5     null complex number during a training process .

1           15.     The apparatus of claim 1 wherein the first signal is a first original signal to  
2     be transmitted.

1           16.     The apparatus of claim 1 wherein the first desired signal is provided to a  
2     first sub-carrier modulator operating at the first frequency.

1           17.     The apparatus of claim 16 further comprising:  
2             a second balancer to generate a second balancing signal from the second signal; and  
3             a second subtractor coupled to the second balancer to subtract the second balancing  
4     signal from the first signal at a second frequency, the second subtractor generating a  
5     second balanced signal at the first frequency.

1           18.     The apparatus of claim 17 wherein the second balancer comprises:  
2             a second converter to convert the second signal into a second complex conjugate;  
3     and  
4             a second multiplier coupled to the second converter to multiply the second complex  
5     conjugate with a second balancing parameter, the second balancing parameter  
6     corresponding to the second frequency, the second multiplier generating the second  
7     balancing signal.

1           19.     The apparatus of claim 17 wherein the second balanced signal is a second  
2     desired signal scaled by a second complex factor.

1           20.     The apparatus of claim 19 wherein the second desired signal is provided to  
2     a second sub-carrier modulator operating at the second frequency.

1           21.     The apparatus of claim 20 wherein one of the first and second balancing  
2 parameters is obtained during a training process.

1           22.     The apparatus of claim 21 wherein the first balancing parameter is derived  
2 from outputs of first and second sub-carrier demodulators operating at first and second  
3 frequencies when the multi-carrier signal is generated from the first and second sub-carrier  
4 modulators receiving the first and second desired signal, the first desired signal being a  
5 non-null complex number and the second desired signal being a null complex number  
6 during the training process.

1           23.     The apparatus of claim 21 wherein the second balancing parameter is  
2 derived from outputs of first and second sub-carrier demodulators operating at first and  
3 second frequencies when the multi-carrier signal is generated from the first and second  
4 sub-carrier modulators receiving the first and second desired signal, the first desired signal  
5 being a null complex number and the second desired signal being a non-null complex  
6 number during the training process.

1           24.     A method comprising:  
2           generating a first balancing signal from a first signal of a first index corresponding  
3 to a first frequency using a first balancer; and  
4           combining the first balancing signal and a second signal of a second index  
5 corresponding to a second frequency using a first combiner, the second frequency being  
6 symmetrical to the first frequency with respect to a center frequency in a multi-carrier  
7 signal, the first combiner generating a first balanced signal corresponding to the second  
8 frequency.

1           25.     The method of claim 24 wherein generating a first balancing signal  
2 comprises:  
3           converting the first signal into a first complex conjugate by a first converter; and

4 multiplying the first complex conjugate with a first balancing parameter by a first  
5 multiplier, the first balancing parameter corresponding to the first frequency, the first  
6 multiplier generating the first balancing signal.

1 26. The method of claim 24 wherein the first combiner includes a first  
2 subtractor to subtract the first balancing signal from the second signal to provide the first  
3 balanced signal.

1 27. The method of claim 24 wherein the first balanced signal is a first desired  
2 signal scaled by a first complex factor.

1 28. The method of claim 27 wherein the first signal is provided by a first sub-  
2 carrier demodulator operating at the first frequency.

1 29. The method of claim 28 wherein the first desired signal is a first  
2 demodulated signal.

1 30. The method of claim 29 further comprising:  
2 generating a second balancing signal from the second signal using a second  
3 balancer; and  
4 combining the second balancing signal with the first signal at a second frequency  
5 using a second combiner, the second combiner generating a second balanced signal at the  
6 first frequency.

1 31. The method of claim 30 wherein generating the second balancing signal  
2 comprises:  
3 converting the second signal into a second complex conjugate by a second  
4 converter; and  
5 multiplying the second complex conjugate with a second balancing parameter by a  
6 second multiplier, the second balancing parameter corresponding to the second frequency,  
7 the second multiplier generating the second balancing signal.

1           32.     The method of claim 30 wherein the second combiner includes a second  
2 subtractor to subtract the second balancing signal from the first signal to provide the  
3 second balanced signal.

1           33.     The method of claim 30 wherein the second balanced signal is a second  
2 desired signal scaled by a second complex factor.

1           34.     The method of claim 33 wherein the second signal is provided by a second  
2 sub-carrier demodulator operating at the second frequency.

1           35.     The method of claim 34 wherein the second desired signal is a second  
2 demodulated signal.

1           36.     The method of claim 30 wherein the first balancing parameter is derived  
2 from outputs of the first and second sub-carrier demodulators when the multi-carrier signal  
3 contains the first sub-carrier signal modulated by a non-null complex number and the  
4 second sub-carrier signal modulated by a null complex number during a training process.

1           37.     The method of claim 30 wherein the second balancing parameter is derived  
2 from outputs of the first and second sub-carrier demodulators when the multi-carrier signal  
3 contains the first sub-carrier signal modulated by a null complex number and the second  
4 sub-carrier signal modulated by a non-null complex number during a training process.

1           38.     The method of claim 26 wherein the first signal is a first original signal to  
2 be transmitted.

1           39.     The method of claim 38 wherein the first desired signal is provided to a first  
2 sub-carrier modulator operating at the first frequency.

1           40.     The method of claim 39 further comprising:

2 generating a second balancing signal from the second signal by a second balancer;  
 3 and  
 4 subtracting the second balancing signal from the first signal at a second frequency  
 5 by a second subtractor, the second subtractor generating a second balanced signal at the  
 6 first frequency.

1 41. The method of claim 40 wherein generating the second balancing signal  
 2 comprises:  
 3 converting the second signal into a second complex conjugate by a second  
 4 converter; and  
 5 multiplying the second complex conjugate with a second balancing parameter by a  
 6 second multiplier, the second balancing parameter corresponding to the second frequency,  
 7 the second multiplier generating the second balancing signal.

1 42. The method of claim 40 wherein the second balanced signal is a second  
 2 desired signal scaled by a second complex factor.

1 43. The method of claim 42 wherein the second desired signal is provided to a  
 2 second sub-carrier modulator operating at the second frequency.

1 44. The method of claim 43 wherein one of the first and second balancing  
 2 parameters is obtained during a training process.

1 45. The method of claim 44 wherein the first balancing parameter is derived  
 2 from outputs of first and second sub-carrier demodulators operating at first and second  
 3 frequencies when the multi-carrier signal is generated from the first and second sub-carrier  
 4 modulators receiving the first and second desired modulating signal, the first desired signal  
 5 being a non-null complex number and the second desired signal being a null complex  
 6 number during the training process.

1 46. The method of claim 44 wherein the second balancing parameter is derived  
 2 from outputs of first and second sub-carrier demodulators operating at first and second

3 frequencies when the multi-carrier signal is generated from the first and second sub-carrier  
4 modulators receiving the first and second desired modulating signal, the first desired signal  
5 being a null complex number and the second desired signal being a non-null complex  
6 number during the training process.

1        47.    A system comprising:  
2        in-phase (I) and quadrature (Q) processing chains to generate I and Q samples from  
3 a multi-carrier signal having P sub-carrier signals at P carrier frequencies;  
4        a bank of demodulators coupled to the I and Q processing chains to demodulate the  
5 P sub-carrier signals, the bank of demodulators generating P demodulated signals; and  
6        a balancing unit coupled to the bank of demodulators to restore P original signals  
7 from the P demodulated signals, the balancing unit including P basic blocks, each of the  
8 basic blocks comprising:  
9                a first balancer to generate a first balancing signal from a first signal at a  
10 first frequency, and  
11                a first subtractor coupled to the first balancer to subtract the first balancing  
12 signal from a second signal at a second frequency, the second frequency being symmetrical  
13 to the first frequency with respect to a center frequency in the multi-carrier signal, the first  
14 subtractor generating a first balanced signal at the second frequency.

1        48.    The system of claim 47 wherein the first balancer comprises:  
2        a first converter to convert the first signal into a first complex conjugate; and  
3        a first multiplier coupled to the first converter to multiply the first complex  
4 conjugate with a first balancing parameter, the first balancing parameter corresponding to  
5 the first frequency, the first multiplier generating the first balancing signal.

1        49.    The system of claim 47 wherein the first combiner includes a first  
2 subtractor to subtract the first balancing signal from the second signal to provide the first  
3 balanced signal.

1        50.    The system of claim 47 wherein the first balanced signal is a first desired  
2 signal scaled by a first complex factor.



1           51.     The system of claim 50 wherein the first signal is provided by a first sub-  
2 carrier demodulator operating at the first frequency.

1           52.     The system of claim 51 wherein the first desired signal is a first  
2 demodulated signal.

1           53.     The system of claim 52 wherein each of the basic blocks further  
2 comprising:  
3           a second balancer to generate a second balancing signal from the second signal; and  
4           a second combiner coupled to the second balancer to combine the second balancing  
5 signal with the first signal at a second frequency, the second combiner generating a second  
6 balanced signal at the first frequency.

1           54.     The system of claim 53 wherein the second balancer comprises:  
2           a second converter to convert the second signal into a second complex conjugate;  
3 and  
4           a second multiplier coupled to the second converter to multiply the second complex  
5 conjugate with a second balancing parameter, the second balancing parameter  
6 corresponding to the second frequency, the second multiplier generating the second  
7 balancing signal.

1           55.     The system of claim 53 wherein the second combiner includes a second  
2 subtractor to subtract the second balancing signal from the first signal to provide the  
3 second balanced signal.

1           56.     The system of claim 53 wherein the second balanced signal is a second  
2 desired signal scaled by a second complex factor.

1           57.     The system of claim 56 wherein the second signal is provided by a second  
2 sub-carrier demodulator operating at the second frequency.

1           58.    The system of claim 57 wherein the second desired signal is a second  
2 demodulated signal.

1           59.    The system of claim 53 wherein the first balancing parameter is derived  
2 from outputs of the first and second sub-carrier demodulators when the multi-carrier signal  
3 contains the first sub-carrier signal modulated by a non-null complex number and the  
4 second sub-carrier signal modulated by a null complex number during a training process.

1           60.    The system of claim 53 wherein the second balancing parameter is derived  
2 from outputs of the first and second sub-carrier demodulators when the training multi-  
3 carrier signal contains the first sub-carrier signal modulated by a null complex number and  
4 the second sub-carrier signal modulated by a non-null complex number during a training  
5 process.

1           61.    The system of claim 49 wherein the first signal is a first original signal to be  
2 transmitted.

1           62.    The system of claim 61 wherein the first desired signal is provided to a first  
2 sub-carrier modulator operating at the first frequency.

1           63.    The system of claim 62 further comprising:  
2           a second balancer to generate a second balancing signal from the second signal; and  
3           a second subtractor coupled to the second balancer to subtract the second balancing  
4 signal from the first signal at a second frequency, the second subtractor generating a  
5 second balanced signal at the first frequency.

1           64.    The system of claim 63 wherein the second balancer comprises:  
2           a second converter to convert the second signal into a second complex conjugate;  
3 and  
4           a second multiplier coupled to the second converter to multiply the second complex  
5 conjugate with a second balancing parameter, the second balancing parameter

6 corresponding to the second frequency, the second multiplier generating the second  
7 balancing signal.

1           65     The system of claim 63 wherein the second balanced signal is a second  
2 desired signal scaled by a second complex factor.

1           66.     The system of claim 65 wherein the second desired signal is provided to a  
2 second sub-carrier modulator operating at the second frequency.

1           67.     The system of claim 66 wherein one of the first and second balancing  
2 parameters is obtained during a training process.

1           68.     The system of claim 67 wherein the first balancing parameter is derived  
2 from outputs of first and second sub-carrier demodulators operating at first and second  
3 frequencies when the multi-carrier signal is generated from the first and second sub-carrier  
4 modulators receiving the first and second desired modulating signal, the first desired signal  
5 being a non-null complex number and the second desired signal being a null complex  
6 number during the training process.

1           69.     The system of claim 67 wherein the second balancing parameter is derived  
2 from outputs of first and second sub-carrier demodulators operating at first and second  
3 frequencies when the training multi-carrier signal is generated from the first and second  
4 sub-carrier modulators receiving the first and second desired modulating signal, the first  
5 desired signal being a null complex number and the second desired signal being a non-null  
6 complex number during the training process.

1           70.     The apparatus of claim 1 wherein at least one of the first and second indices  
2 corresponds to a zero index.

1           71.     The apparatus of claim 70 wherein at least one of the first and second  
2 signals corresponds to one of the center frequency and a DC of a baseband signal of the  
3 multi-receiver signal.